



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04L 5/06, 27/26	A2	(11) International Publication Number: WO 98/10556 (43) International Publication Date: 12 March 1998 (12.03.98)
(21) International Application Number: PCT/SE97/01461 (22) International Filing Date: 1 September 1997 (01.09.97) (30) Priority Data: 9603198-4 2 September 1996 (02.09.96) SE (71) Applicant (for all designated States except US): TELIA AB [SE/SE]; Mårbackagatan 11, S-123 86 Farsta (SE). (72) Inventors; and (75) Inventors/Applicants (for US only): ISAKSSON, Mikael [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). JOHANSSON, Magnus [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). TONVALL, Harry [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). OLSSON, Lennart [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). STEFANSSON, Tomas [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ÖHMAN, Hans [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). BAHLENBERG, Gunnar [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ISAKSSON, Anders [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ÖKVIST, Göran [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). LJUNGGREN, Lis-Marie [SE/SE]; Telia Research AB,		Aurorum 6, S-977 75 Luleå (SE). NORDSTRÖM, Tomas [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ISAKSSON, Lars-Åke [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). BENGTSSON, Daniel [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). HÅKANSSON, Siwert [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). WEN, Ye [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). (74) Agent: KARLSSON, Berne; Telia Research AB, Rudsjöterrassen 2, S-136 80 Haninge (SE). (81) Designated States: JP, NO, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>Without international search report and to be republished upon receipt of that report.</i>
(54) Title: IMPROVEMENTS IN, OR RELATING TO, MULTI-CARRIER TRANSMISSION SYSTEMS		
(57) Abstract <p>The invention relates to a multi-carrier transmission system, particularly a DMT system, in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, the transmission system being adapted for operation in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations. In accordance with the invention the transmission system includes allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth.</p>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

- 1 -

**IMPROVEMENTS IN, OR RELATING TO, MULTI-CARRIER
TRANSMISSION SYSTEMS**

5 The invention relates to multi-carrier transmission systems and, in particular, a method for the allocation of tones in such systems, and a heterogeneous telecommunications network including a multi-carrier transmission system.

10 The demand for provision of multi-media and other bandwidth services over telecommunications networks has created a need to transmit high bit rate traffic over twisted copper pairs. This requirement has led to the development of a number of different transmission schemes,
15 such as, ADSL and VDSL. One of the more likely modulation systems for all these transmission schemes is DMT, which bears some resemblance to orthogonal frequency division multiplex, and is a spread spectrum transmission technique.

20 In discrete multi-tone transmission, the available bandwidth is divided into a plurality of sub-channels each with a small bandwidth, 4 kHz perhaps. Traffic is allocated to the different sub-channels in dependence on
25 noise power and transmission loss in each sub-channel. Each channel carries multi-level pulses capable of representing up to 11 data bits. Poor quality channels carry fewer bits, or may be completely shut down.

30 Because inter pair interference in copper pair cables is higher where data is transmitted in both directions, i.e. symmetric duplex, the use of asymmetric schemes has been proposed in which high data rates are transmitted in one direction only. Such schemes meet many of the demands
35 for high bandwidth services, such as, video-on-demand but,

- 2 -

in the long term, symmetric duplex systems will be required.

VDSL (Very high bit-rate Digital Subscriber Lines) technology resembles ADSL to a large degree, although ADSL must cater for much larger dynamic ranges and is considerably more complex as a result. VDSL is lower in cost and lower in power, and premises VDSL units need to implement a physical layer media access control for multiplexing upstream data.

Four line codes have been proposed for VDSL:

- CAP; Carrierless AM/PM, a version of suppressed carrier Quadrature Amplitude Modulation (QAM), for passive Network termination (NT) configurations, CAP would use QPSK upstream and a type of Time Division Multiple Access (TDMA) for multiplexing (although CAP does not preclude a Frequency Division Multiplexing (FDM) approach to upstream multiplexing);
- DMT; Discrete Multi-Tone, a multi-carrier system using Discrete Fourier Transforms to create and demodulate individual carriers, for passive NT configurations; DMT would use FDM for upstream multiplexing (although DMT does not preclude a TDMA multiplexing strategy);
- DWMT; Discrete Wavelet Multi-Tone, a multi-carrier system using Wavelet Transforms to create and demodulate individual carriers, DWMT also uses FDM for upstream multiplexing, but also allows TDMA; and

- 3 -

- SLC; Simple Line Code, a version of four-level baseband signalling that filters the base band and restores it at the receiver, for passive NT configurations; SLC would most likely use TDMA for upstream multiplexing, although FDM is possible.

Early versions of VDSL will use frequency division multiplexing to separate downstream from upstream channels and both of them from POTS and ISDN. Echo cancellation may be required for later generation systems featuring symmetric data rates. A rather substantial distance, in frequency, will be maintained between the lowest data channel and POTS to enable very simple and cost effective POTS splitters. Normal practice would locate the downstream channel above the upstream channel. However, the DAVIC specification reverses this order to enable premises distribution of VDSL signals over coaxial cable systems.

Modern multi-carrier techniques using orthogonal carriers with high order QAM constellations for the transmission of a plurality of bits per carrier and symbol, use some method for the determination of an inverse channel model to be used in an equalization process. In the frequency domain, this is normally based on an estimate of the channel attenuation and phase for each carrier.

In a heterogeneous network, a number of users with different channel characteristics will coexist on the same cable and there is a need, with such networks, to be able to utilise the capacity of the network in a manner whereby coverage is optimised.

- 4 -

It is an object of the present invention to provide a multi-carrier transmission systems operating in a heterogeneous network and adapted to utilise the capacity of the network in a manner whereby coverage is optimised.

5

It is another object of the present invention to provide a method for the allocation of tones in a multi-carrier transmission system operating in a heterogeneous network. This method will not only enable the capacity of the network to be utilised in a manner whereby coverage is optimised, but will also enable the number of subscribers, covered by a VDSL system, to grow.

10

It is a further object of the present invention to provide a heterogeneous telecommunications network including a multi-carrier transmission system.

15

The present invention provides a multi-carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, said transmission system being adapted for operation in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations, characterised in that said transmission system includes allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated by said allocation means, to subscriber equipments having relatively longer lengths

20

25

30

35

- 5 -

of cable. The usable frequency band of said system bandwidth for subscriber equipments having relatively longer lengths of cable may be determined by said noise level of the system.

5

The present invention also provides a heterogeneous network including a multi-carrier transmission system as outlined in preceding paragraphs.

10 The present invention further provides a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their
15 respective locations; and a multi-carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, characterised in that said
20 transmission system includes allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth thereby reducing interference in a lower frequency band and giving an
25 improved signal-to-noise ratio on tones, above a noise level of the system, allocated by said allocation means to subscriber equipments having relatively longer lengths of cable. The usable frequency band of said system bandwidth for subscriber equipments having relatively longer lengths
30 of cable is determined by said noise level of the system.

The allocation means may be adapted to operate in accordance with a tone allocation algorithm which may operate independently of the order in which said
35 subscriber equipments, having shorter and longer lengths

- 6 -

of cable connections, use said network.

The present invention further provides, in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations; and a multi-carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, a method for the allocation of tones in said multi-carrier transmission system, characterised by allocating the traffic of a subscriber terminal having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated to a subscriber terminal having a longer length of cable. The usable frequency band of said system bandwidth for subscriber equipments having longer lengths of cable may be determined by said noise level of the system.

25

The invention further provides a method for the allocation of tones in a DMT transmission system operating in a heterogeneous network, characterised by network users, having cable connections shorter in length than cable connections of other users, allocating their traffic to tones starting from high frequencies of said transmission system's frequency bandwidth thereby reducing, in a mixed network, interference in a low frequency band of said system frequency bandwidth and giving network uses, having relatively longer cable

35

- 7 -

connections, an improved SNR on the tones available above a noise level of the DMT system.

5 The tone allocation process may be effected in accordance with a tone allocation algorithm which may operate independently of the order in which said subscriber equipments, having shorter and longer lengths of cable connections, use said network.

10 The multi-carrier transmission system may be a DMT transmission system.

 The multi-carrier transmission system may be a DMT based VDSL system.

15 The system bandwidth may be 10 MHz and may be divided into 1024 carriers each having a width of 9.77 kHz.

20 The foregoing and other features of the present invention will be better understood from the following description with reference to the accompanying drawings, in which:

25 Figure 1 illustrates, in schematic form, an asymmetric communications system;

 Figure 2 illustrates, in schematic form, a DMT system;

30 Figure 3 illustrates, graphically, the channel separations used in an asymmetric DMT transmission system;

35 Figure 4 diagrammatically illustrates the cable section of a heterogenous (multimedia) network;

- 8 -

Figure 5 illustrates, graphically, attenuation curves for the network of Figure 4;

Figure 6 illustrates, in graphical form, the dependence of signal-to-noise ratio on frequency for a DMT system;

Figure 7 illustrates, graphically, attenuation curves for the network of Figure 4, operating in accordance with the present invention; and

Figure 8 illustrates, in schematic form, a network overview for a VDSL modem application network interface.

To facilitate an understanding of the present invention, a glossary of the abbreviations used in this patent specification are set out below:

ADC: Analog-to-Digital Converter

DAC: Digital-to-Analog Converter

DMT: Discrete Multi Tone

DWMT: Discrete Wavelet Multi-Tone

FFT: Fast Fourier Transform

FITN: Fibre To The Node

MUSIC: Multi-carrier System for the Installed Copper network

IFFT: Inverse Fast Fourier Transform

ISDN: International Standard for Digital Networks

- 9 -

NT: Network Termination

NU: Network Unit

5

POTS: Plain Old Telephony Service

QAM: Quadrature Amplitude Modulation

10

SDH: Synchronous Digital Hierarchy

SNR: Signal-to-Noise Ratio

TDMA: Time Division Multiple Access

15

VDSL: Very high bit-rate Digital Subscriber Lines

20

The system, to which the present invention generally relates, is for convenience referred to as MUSIC - Multi-carrier System for the Installed Copper network. MUSIC is intended to provide high-speed communication on telephone twisted copper wire pairs for supporting broadband multimedia services.

25

The MUSIC system is adapted to offer a cost-effective robust customer implementation in silicon, providing 26:2 or 13:2 Mbps asymmetric transmission over copper cables (<1300 metres) for use on existing local telephony networks.

30

The MUSIC system can be accessed using the network concept known as Fibre To The Node (FITN), using optical fibres, each serving many users, up to a cabinet near the users' homes. Thus, the cable length specification for
35 MUSIC can be successfully limited to 1300 metres.

- 10 -

The MUSIC system is primarily intended for the transmission of a high (26 Mbps) bit-rate signal downstream to the subscriber and a low (2 Mbps) bit-rate signal upstream, from the subscriber.

Figure 1 illustrates the MUSIC system. A network unit, NU, is connected to the fixed network by an optical fibre link, (FITN). A network termination, NT, connected to a multimedia application, e.g. video on demand, is linked to the NU via copper cable. The MUSIC system supports a high down stream data rate and a much lower up stream data rate.

In the MUSIC system, described herein, two fixed bit rates (13:2, 26:2 Mbps) are supported, the lower bit rate, 13:2 Mbps, can be implemented as an extra option for use with poor, or extremely long, copper cables.

For the network termination (NT), the connection consists of a set of standard interfaces, such as, POTS, ISDN, ATM 25 and Ethernet. All transfer protocols are carried by the modem data stream, except for the POTS service, which is passively filtered out so that it is independent of modem status. The network unit (NU) terminates in the fixed network.

MUSIC separates the up and down-link spectra by passive filtering in the analog parts.

The version of MUSIC, described herein, is intended to allow for future functionality upgrades.

The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and

- 11 -

demodulate individual carriers. This is illustrated in Figure 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality.

A multi-carrier modulation technique, i.e. DMT, handles frequency dependent loss and noise in twisted pair-cables in an efficient manner. In the MUSIC system, the available 10 MHz bandwidth is divided into 1024 carriers each of which is 9.77 kHz wide. The allocated transmission power for the individual carriers depends on the noise power and the transmission loss in each band. Every carrier carries multilevel pulses that can represent up to 12 bits of data (4096 QAM). The individual carrier's signal-to-noise ratio (SNR) is calculated on the receiver side. If a carrier has a high SNR, up to 12 bits are placed on that carrier. For carriers with low SNR values, fewer bits are placed on the carrier. Carriers affected by narrow band interferers are turned off. Forward error correction and data interleaving is used to mitigate the effects of occasional bursts of impulse noise.

Asymmetric VDSL is implemented in this version of the MUSIC system, which means that the downstream rate is much higher than the upstream rate. Two fixed downstream rates (26/13 Mbps) are supported by the system, the chosen rate depends on the actual cable length (< 1300 meters) and/or the quality of the channel. The upstream rate is fixed at 2 Mbps. Different frequency bands can be used in the MUSIC system to separate the downstream channel from

- 12 -

upstream channel and both from POTS, see Figure 3.

Alternatively, other duplex methods can be used, for example, TDMA and/or a method where every other carrier is
5 dedicated for the downstream and upstream channel.

It will be seen from Figure 4 of the accompanying drawings, which diagrammatically illustrates the cable section of a heterogeneous network, i.e. a multi-carrier
10 system, such as MUSIC, which is intended to provide high-speed communication on telephone copper wire pairs for supporting broadband multimedia services. As shown in Figure 4, the cable 1 of the heterogeneous (multimedia) network is a multi-core cable, each core of which is a
15 twisted pair of copper cables, for example, the copper wire pairs 2 and 3, respectively for users (subscribers) 'A' and 'B' of the network. Thus, subscribers 'A' and 'B', are connected to the network by means of cables of different lengths, i.e. the length of the cable 3, for
20 subscriber 'B' is longer than the length of cable 2, for subscriber 'A'.

As shown by the attenuation curves of Figure 5 of the accompanying drawings, the shorter length of cable 2 for
25 subscriber 'A' has less attenuation in the higher frequency band of the system frequency range, or bandwidth, than the longer length of cable 3 for subscriber 'B'.

It will also be seen from Figure 6 which illustrates, in graphical form, the dependence of signal-to-noise ratio (SNR) on frequency for a multi-tone carrier transmission system, that the shorter length of cable 2 has less
30 attenuation in the higher frequency range than the longer length of cable 3. This means that, for shorter length
35

- 13 -

cables, an occasional pulse may appear in the system's receiver almost unchanged. Hence, a relatively large dynamic range in the receiver is required. However, this can be readily achieved since almost uniform attenuations
5 do not require a large dynamic range. The ADC (Analog-to-Digital Converter) needs to accommodate the region indicated in Figure 6 by the heavy solid arrowed line.

The larger high frequency attenuations of longer
10 length cables does, however, require a large dynamic range in the receiver. The high frequency attenuation also means that it would take several large peaks from a transmitter in order to build up high amplitudes in the receiver, a case which is even less likely to occur at the
15 ADC input than single peaks. The headroom can, therefore, be decreased by the heavy dashed arrowed line, in Figure 6.

Thus, in practice, performance can be optimised by
20 carefully setting the signal level at the receiver ADC in dependence on cable length.

It will be seen from the foregoing that the shape of the curves in Figure 5 are, in essence, the result of two
25 effects, namely, attenuation and the interference generated by other users in the same cable (see Figure 4).

The capacity of the cable of Figure 4 is the area between the two curves, illustrated in Figure 5, for each
30 of the subscribers 'A' and 'B', i.e. the dotted curves for subscriber 'A' and solid curves for subscriber 'B', lying above the noise floor, i.e. a noise level of the system, and within the frequency bandwidth of the system.

The usable frequency range for subscriber 'B' is less
35 than the usable frequency range for subscriber 'A'.

- 14 -

In accordance with the present invention, a method is provided for the allocation of tones in a DMT system operating in a heterogeneous network, for example, a mixed (multimedia) network employing VDSL. This method will not only enable the capacity of the heterogeneous network to be utilised in a manner whereby coverage is optimised, but will also enable the number of subscribers, covered by a VDSL system, to grow.

10

As stated above, a DMT-based VDSL system is a multi-carrier system using Discrete Fourier Transforms to create and demodulate individual carriers. A modulation technique, such as DMT, can handle frequency dependent loss and noise in twisted pair-cables in an efficient manner.

15

In accordance with the method of tone allocation, subscribers, such as subscriber 'A', with short cable lengths will allocate their traffic to tones starting from the high frequencies. The effect of this, in a heterogeneous network, is that interference in the low frequency band will be reduced thereby giving subscriber 'B', i.e. subscribers with longer cable lengths, a better signal-to-noise ratio (SNR) on the tones available above the noise floor. This effect is shown in Figure 7 of the accompanying drawings.

20

25

Thus, the algorithm used for the tone allocation method is adapted to allocate tones, with the given system margin, starting from the highest frequency and thus cover longer cables.

30

Use of the tone allocation algorithm is not time related, i.e. there is no temporal aspect of the algorithm, and, as a consequence of this, the allocation

35

- 15 -

process will operate in the same way regardless of the time at which the network is used by subscribers 'A' and 'B'.

5 In other words, allocation means, forming part of the multi-carrier transmission system, are adapted to operate in accordance with a tone allocation algorithm which operates independently of the order in which the subscribers 'A' and 'B', respectively having shorter and
10 longer lengths of cable connections, use the heterogeneous, or multimedia, network.

 It will, therefore, be seen from the foregoing that a multi-carrier transmission system, such as a DMT system,
15 in which data is transmitted between two transceivers using a plurality of carriers, and in which the frequency bandwidth of the system is divided between the plurality of carriers, is adapted for operation in a heterogeneous network and to utilise the capacity of the network in a
20 manner whereby coverage is optimised.

 It will also be seen that in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the
25 same cable, in which the length of cable for each subscriber terminal varies in dependence on their respective locations, the multi-carrier transmission system uses allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to
30 tones starting from a higher frequency band within the system bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated by said allocation means, to subscriber
35 equipments having relatively longer lengths of cable. In

- 16 -

essence, the usable frequency band of the system bandwidth for subscriber equipments having relatively longer lengths of cable is determined by the system noise level.

5 The multi-carrier transmission system is preferably a DMT based VDSL system having a bandwidth of 10 MHz divided into 1024 carriers each having a width of 9.77 kHz.

10 In a mixed (multimedia) network employing VDSL, the VDSL modem can interface different network elements, depending on the physical location of the modem, i.e. at the access node premises, or at the customer premises. At the customer premises, the VDSL modem can interface an active network termination equipment. At the access node,
15 the VDSL modem will interface an access specific interface, see Figure 8, which shows a logical view of the network's elements that interface the VDSL modem.

20 The VDSL modem may be integrated physically with the network termination equipment, and the VDSL modem, at the access node, may be physically situated in the cabinet in which the access node is located.

25 The NT (interface A1) and the Access Node (interface A2) demand a layer 1 frame format from the VDSL modem. Integrated in the layer 1 frame are, apart from the frame header and payload, a number of information fields for management and control information. These management and control fields include different alarm indicators such as
30 SDH alarms, for example, AIS (valid only if SDH is taken all the way to the customer premises) bit error rate measurements for performance monitoring, indications of whether synchronization is bad, or lost, equipment handling alarms for power loss and high temperature etc.
35 The management fields also include activation for

- 17 -

different loop tests on the modem, for operation and maintenance purposes.

CLAIMS

1. A multi-carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, said transmission system being adapted for operation in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations, characterised in that said transmission system includes allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated by said allocation means, to subscriber equipments having relatively longer lengths of cable.

2. A multi-carrier transmission system as claimed in claim 1, characterised in that the usable frequency band of said system bandwidth for subscriber equipments having relatively longer lengths of cable is determined by said noise level of the system.

3. A multi-carrier transmission system as claimed in claim 1, or claim 2, characterised in that said allocation means are adapted to operate in accordance with a tone allocation algorithm.

4. A multi-carrier transmission system as claimed in claim 3, characterised in that said tone allocation

- 19 -

algorithm operates independently of the order in which said subscriber equipments, having shorter and longer lengths of cable connections, use said network.

5 5. A multi-carrier transmission system as claimed in any previous claim, characterised in that said multi-carrier transmission system is a DMT transmission system.

10 6. A multi-carrier transmission system as claimed in any previous claim, characterised in that said multi-carrier transmission system is a DMT based VDSL system.

15 7. A multi-carrier transmission system as claimed in any previous claim, characterised in that said system bandwidth is 10 MHz.

20 8. A multi-carrier transmission system as claimed in claim 7, characterised in that said system bandwidth is divided into 1024 carriers each having a width of 9.77 kHz.

9. A heterogeneous network including a multi-carrier transmission system as claimed in any previous claim.

25 10. A heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations; and a multi-
30 carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, characterised in that said transmission system includes allocation means for
35 allocating the traffic of subscriber equipments having a

- 20 -

shorter length of cable to tones starting from a higher frequency band of said system bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated by said allocation means to subscriber equipments having relatively longer lengths of cable.

11. A heterogeneous network as claimed in claim 10, characterised in that the usable frequency band of said system bandwidth for subscriber equipments having relatively longer lengths of cable is determined by said noise level of the system.

12. A heterogeneous network as claimed in claim 10, or claim 11, characterised in that said allocation means are adapted to operate in accordance with a tone allocation algorithm.

13. A heterogeneous network as claimed in claim 12, characterised in that said tone allocation algorithm operates independently of the order in which said subscriber equipments, having shorter and longer lengths of cable connections, use said network.

14. A heterogeneous network as claimed in any of claims 10 to 13, characterised in that said multi-carrier transmission system is a DMT transmission system.

15. A heterogeneous network as claimed in any of claims 10 to 14, characterised in that said multi-carrier transmission system is a DMT based VDSL system.

16. A heterogeneous network as claimed in any of claims 10 to 15, characterised in that said system bandwidth is

- 21 -

10 MHz.

17. A heterogeneous network as claimed in claim 16, characterised in that said system bandwidth is divided
5 into 1024 carriers each having a width of 9.77 kHz.

18. In a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the
10 length of cable for each subscriber terminal varying in dependence on their respective locations; and a multi-carrier transmission system in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided
15 between said plurality of carriers, a method for the allocation of tones in said multi-carrier transmission system, characterised by allocating the traffic of a subscriber terminal having a shorter length of cable to tones starting from a higher frequency band of said system
20 bandwidth thereby reducing interference in a lower frequency band and giving an improved signal-to-noise ratio on tones, above a noise level of the system, allocated to a subscriber terminal having a longer length of cable.

25 19. A method as claimed in claim 18, characterised in that the usable frequency band of said system bandwidth for subscriber equipments having longer lengths of cable is determined by said noise level of the system.

30 20. A method as claimed in claim 18, or claim 19, characterised in that the tone allocation process is effected in accordance with a tone allocation algorithm.

35 21. A method as claimed in claim 20, characterised in

- 22 -

that the tone allocation algorithm operates independently of the order in which said subscriber equipments, having shorter and longer lengths of cable connections, use said network.

5

22. A method as claimed in any of claims 18 to 21, characterised in that said multi-carrier transmission system is a DMT transmission system.

10

23. A method as claimed in any of claims 18 to 22, characterised in that said multi-carrier transmission system is a DMT based VDSL system.

15

24. A method as claimed in any of claims 18 to 23, characterised in that said system bandwidth is 10 MHz.

25. A method as claimed in claim 24, characterised in that said system bandwidth is divided into 1024 carriers each having a width of 9.77 kHz.

20

26. A method for the allocation of tones in a DMT transmission system operating in a heterogeneous network, characterised by network users, having cable connections shorter in length than cable connections of other users, allocating their traffic to tones starting from high frequencies of said transmission system's frequency bandwidth thereby reducing, in a mixed network, interference in a low frequency band of said system frequency bandwidth and giving network uses, having relatively longer cable connections, an improved SNR on the tones available above a noise level of the DMT system.

30

27. A method as claimed in claim 26, characterised in that said transmission system is a DMT based VDSL system.

35

1/4

Fig. 1

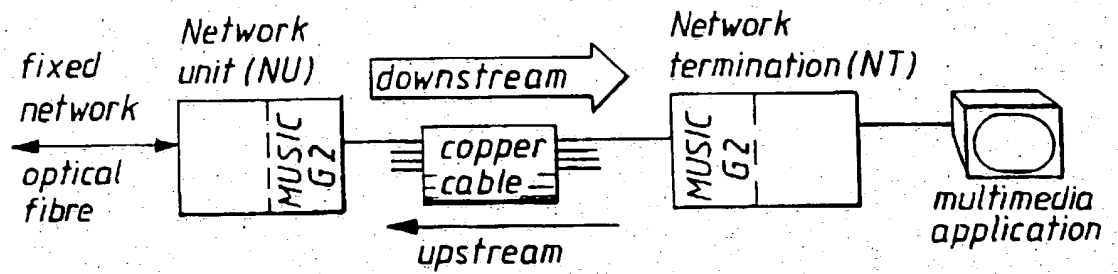


Fig. 2

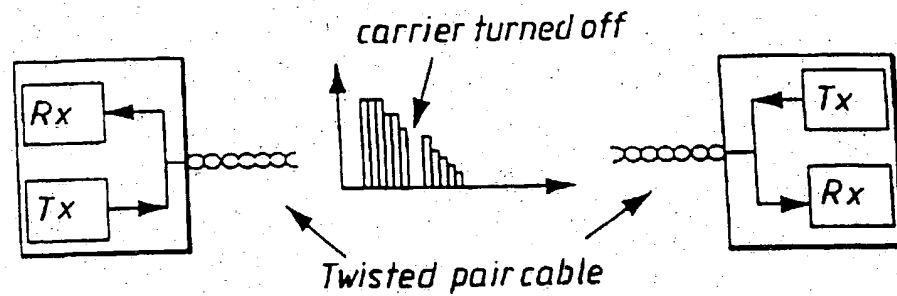
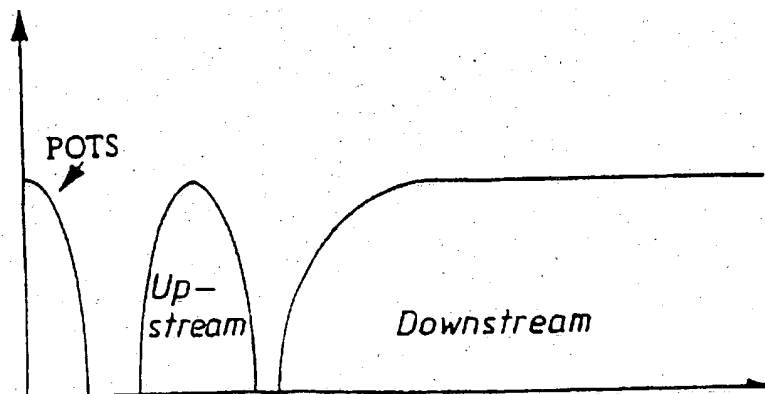


Fig. 3



2 / 4

Fig. 4

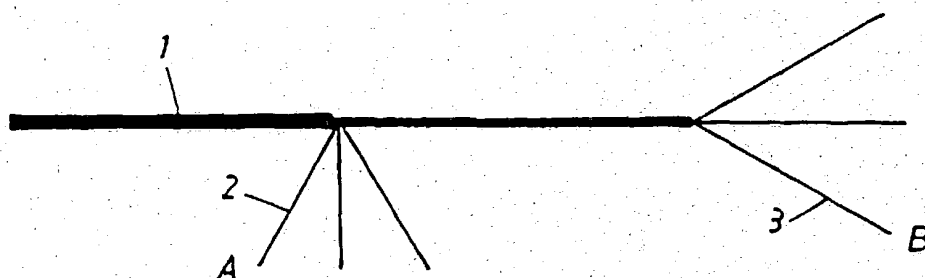
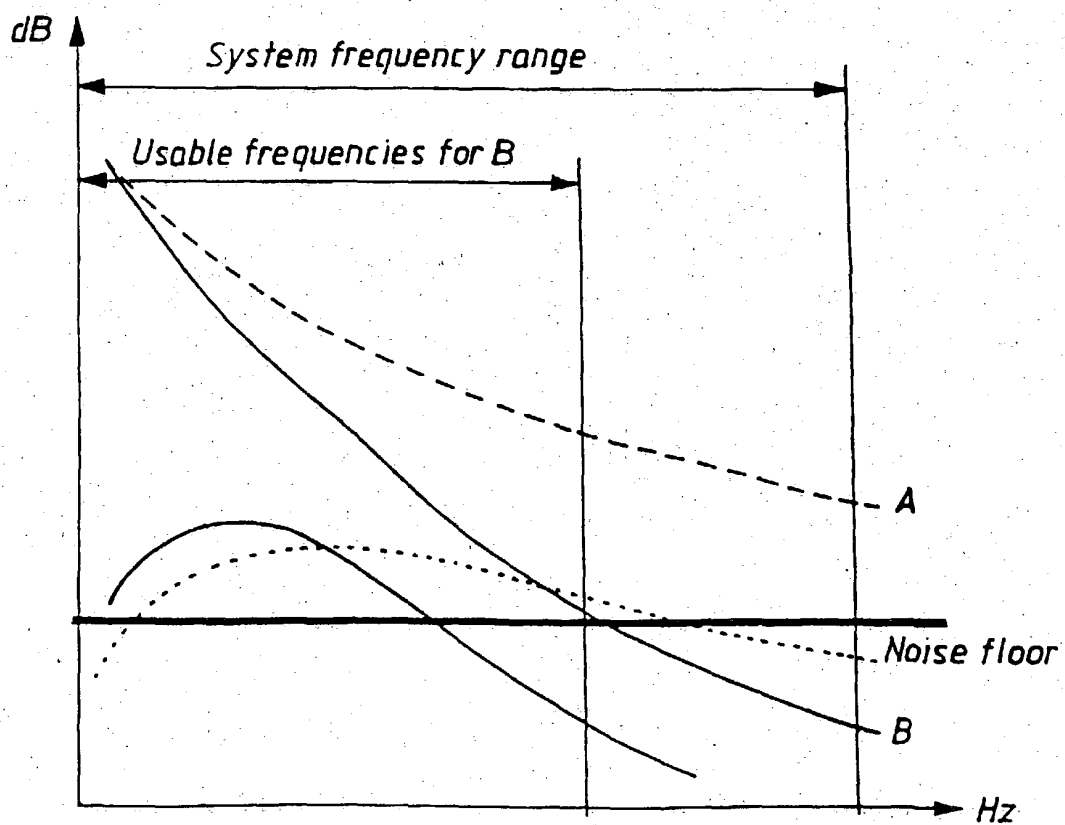


Fig. 5



3 / 4

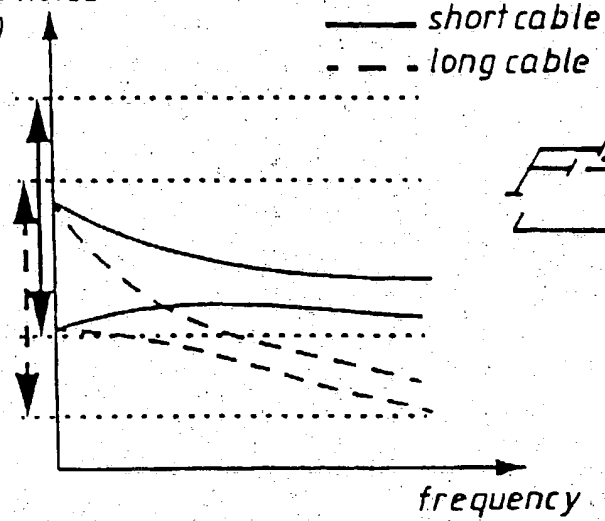
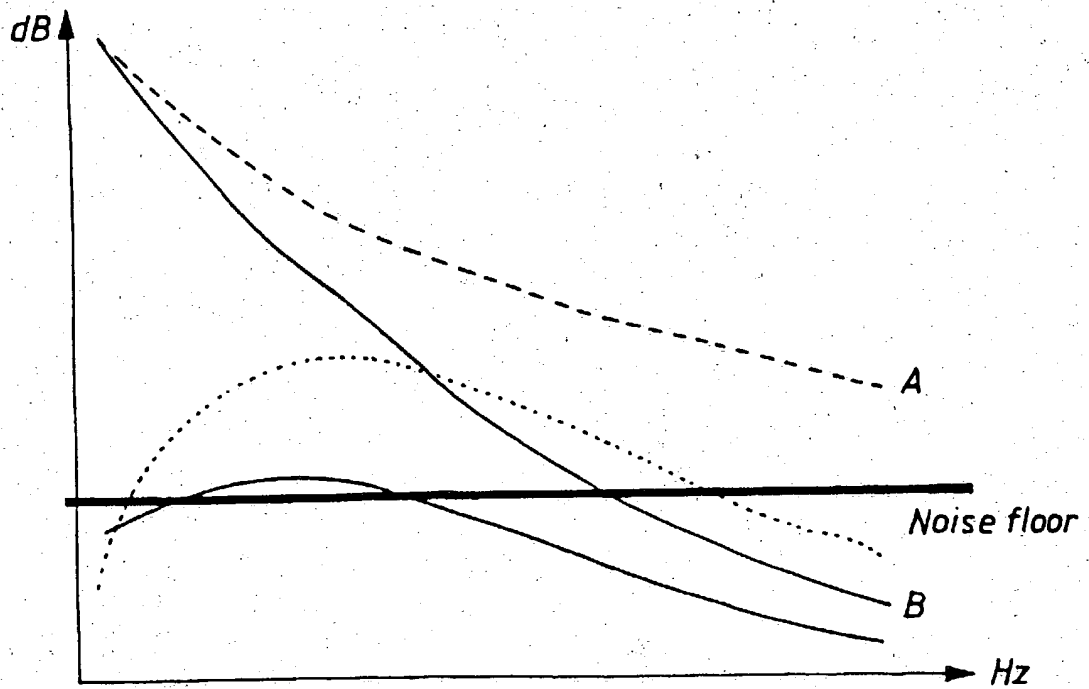
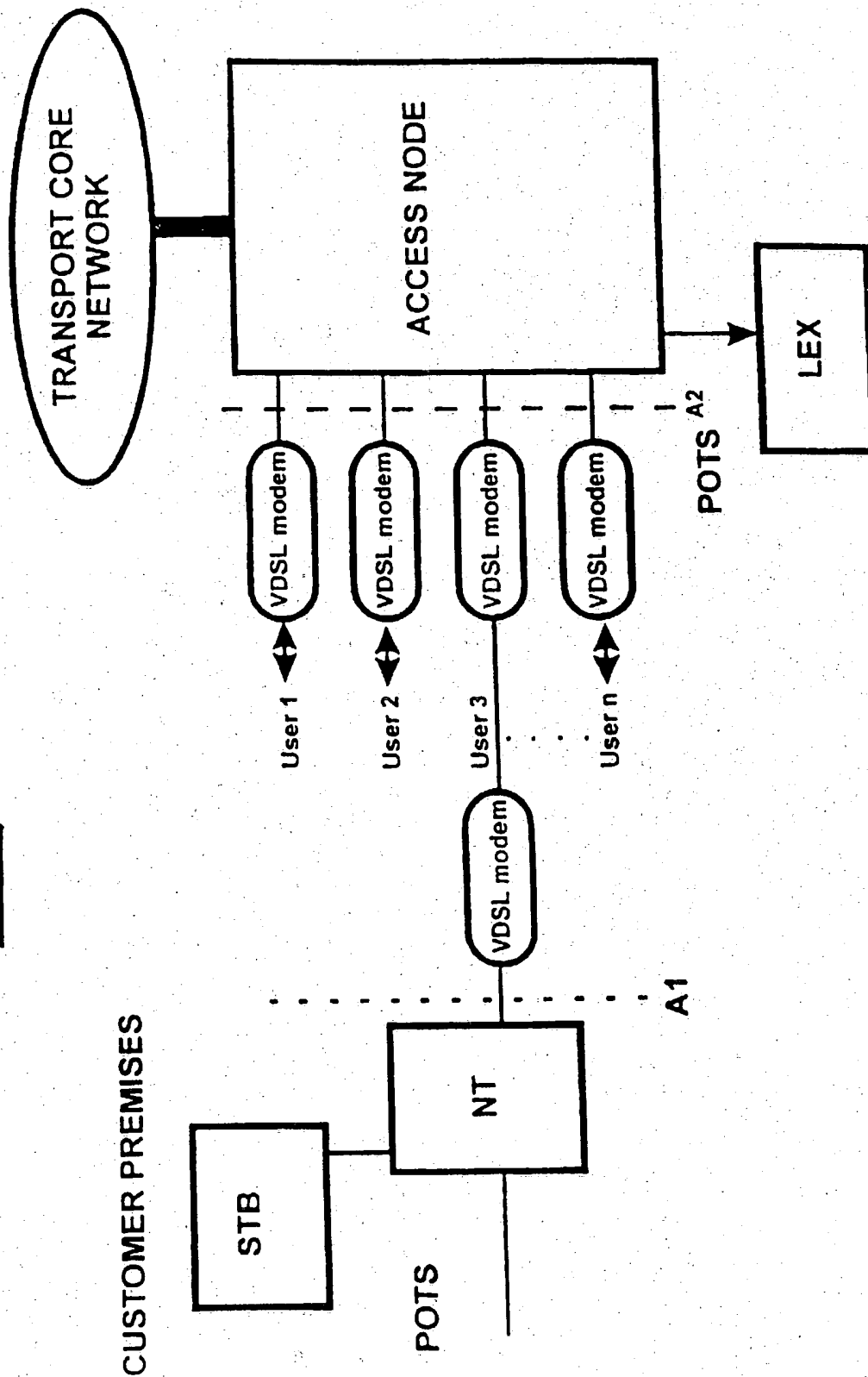
Signal and noise
levels (dB)

Fig. 7



4 / 4

Fig. 8

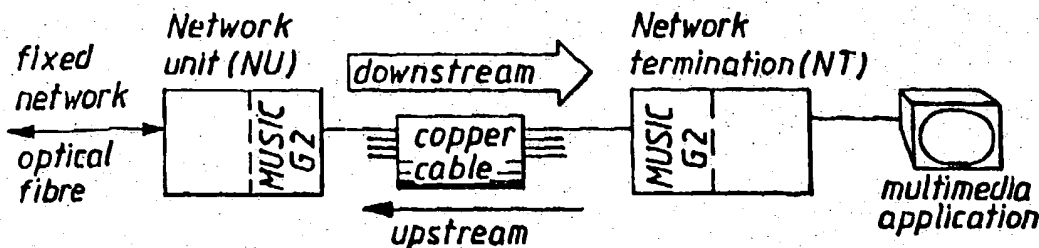




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04L 5/06, 27/26		A3	(11) International Publication Number: WO 98/10556
			(43) International Publication Date: 12 March 1998 (12.03.98)
(21) International Application Number: PCT/SE97/01461		Aurorum 6, S-977 75 Luleå (SE). NORDSTRÖM, Tomas [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ISAKSSON, Lars-Åke [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). BENGTSOON, Daniel [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). HÅKANSSON, Siwert [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). WEN, Ye [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). (74) Agent: KARLSSON, Berne; Telia Research AB, Rudsjötterrassen 2, S-136 80 Haninge (SE). (81) Designated States: JP, NO, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> (88) Date of publication of the international search report: 4 June 1998 (04.06.98)	
(22) International Filing Date: 1 September 1997 (01.09.97)			
(30) Priority Data: 9603198-4 2 September 1996 (02.09.96) SE			
(71) Applicant (for all designated States except US): TELIA AB [SE/SE]; Mårbackagatan 11, S-123 86 Farsta (SE).			
(72) Inventors; and (75) Inventors/Applicants (for US only): ISAKSSON, Mikael [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). JOHANSSON, Magnus [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). TONVALL, Harry [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). OLSSON, Lennart [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). STEFANSSON, Tomas [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ÖHMAN, Hans [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). BAHLENBERG, Gunnar [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ISAKSSON, Anders [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). ÖKVIST, Göran [SE/SE]; Telia Research AB, Aurorum 6, S-977 75 Luleå (SE). LJUNGGREN, Lis-Marie [SE/SE]; Telia Research AB,			

(54) Title: IMPROVEMENTS IN, OR RELATING TO, MULTI-CARRIER TRANSMISSION SYSTEMS



(57) Abstract

The invention relates to a multi-carrier transmission system, particularly a DMT system, in which data is transmitted between two transceivers using a plurality of carriers, the frequency bandwidth of the system being divided between said plurality of carriers, the transmission system being adapted for operation in a heterogeneous network including a number of subscriber equipments having different channel characteristics and coexisting on the same cable, the length of cable for each subscriber terminal varying in dependence on their respective locations. In accordance with the invention the transmission system includes allocation means for allocating the traffic of subscriber equipments having a shorter length of cable to tones starting from a higher frequency band of said system bandwidth.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Sénégal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 97/01461

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 5/06, H04L 27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IEEE TRANSACTIONS ON BROADCASTING PP 1-8, Volume 41, No 1, March 1995, William y. Zou et al, "COFDM: AN OVERVIEW", see whole document -----	1-27

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "B" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 March 1998

Date of mailing of the international search report

16 -03- 1998

Name and mailing address of the ISA/
Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Mikael Sollerhed
Telephone No. +46 8 782 25 00